# Watershed Report for Biological Impairment of the Bynum Run Watershed in Harford County, Maryland Biological Stressor Identification Analysis Results and Interpretation

## FINAL

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## List of Abbreviations

| | |
|---|---|
| AR | Attributable Risk |
| BIBI | Benthic Index of Biotic Integrity |
| BSID | Biological Stressor Identification |
| COMAR | Code of Maryland Regulations |
| CWA | Clean Water Act |
| DO | Dissolved Oxygen |
| FIBI | Fish Index of Biologic Integrity |
| IBI | Index of Biotic Integrity |
| MBSS | Maryland Biological Stream Survey |
| MDDNR | Maryland Department of Natural Resources |
| MDE | Maryland Department of the Environment |
| MH | Mantel-Haenzel |
| mg/L | Milligrams per liter |
| MS4 | Municipal Separate Storm Sewer System |
| $NH_3$ | Ammonia |
| NPDES | National Pollutant Discharge Elimination System |
| PCBs | Polychlorinated Biphenyls |
| SCS | Soil Conservation Service |
| SSURGO | Soil Survey Geographic |
| TMDL | Total Maximum Daily Load |
| µS/cm | Micro Siemens per centimeter |
| USEPA | United States Environmental Protection Agency |
| WQA | Water Quality Analysis |
| WQLS | Water Quality Limited Segment |

## Executive Summary

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met.

The Bynum Run watershed (basin code 02130704), located in Harford County, was identified on the States list of WQLSs and listed in the *Integrated Report* under Category 5 as impaired by sediments, nutrients (1996 listings), impacts to biological communities (2002 listing) and polychlorinated biphenyls (PCBs)(2006 listing). The Bynum Run watershed was de-listed for nutrients in 2007 following USEPA concurrence with Maryland Department of the Environment's (MDE) analysis of water column data collected during 1998-2004, which showed no nutrient impairment.

In 2002, the State began listing biological impairments on the *Integrated Report*. The current MDE biological assessment methodology assesses and lists only at the Maryland 8-digit watershed scale, which maintains consistency with other listings on the Integrated Report are made, TMDLs are developed, and how implementation is targeted. The listing methodology assesses the condition of Maryland 8-digit watersheds by measuring the percentage of stream miles that have poor to very poor biological conditions, and calculating whether this is a significant deviation from a reference condition watershed (i.e., healthy stream, <10% stream miles with poor to very poor biological condition).

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Bynum Run watershed is Use III – *nontidal cold water* for the mainstem and all tributaries. In addition, COMAR requires these waterbodies to support at a minimum the Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life* (COMAR a, b). The Bynum Run watershed is not attaining its Use I designation because of biological impairments. As an indicator of designated use attainment, MDE uses Benthic and Fish Indices of Biotic Integrity (BIBI/FIBI) developed by the Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS).

The current listings for biological impairments represent degraded biological conditions for which the stressors, or causes, are unknown. The MDE Science Services Administration (SSA) has developed a biological stressor identification (BSID) analysis that uses a case-control, risk-based approach to systematically and objectively determine

the predominant cause of reduced biological conditions, thus enabling the Department to most effectively direct corrective management action(s). The risk-based approach, adapted from the field of epidemiology, estimates the strength of association between various stressors, sources of stressors and the biological community, and the likely impact this stressor has on the degraded sites in the watershed.

The BSID analysis uses data available from the statewide MDDNR MBSS. Once the BSID analysis is completed, a number of stressors (pollutants) may be identified as probable or unlikely causes of poor biological conditions within the Maryland 8-digit watershed study. BSID analysis results can be used as guidance to refine biological impairment listings in the Integrated Report by specifying the probable stressors and sources linked to biological degradation.

This Bynum Run watershed report presents a brief discussion of the BSID process on which the watershed analysis is based, and which may be reviewed in more detail in the report entitled *Maryland Biological Stressor Identification Process* (MDE 2009). Data suggest that the biological communities of the Bynum Run watershed are strongly influenced by urban land use and its concomitant effects: altered hydrology and increased pollutant loading from urban runoff resulting in elevated levels of ammonia. The urbanization of landscapes creates broad and interrelated forms of degradation (i.e., hydrological, morphological, and water chemistry) that can affect stream ecology and biological composition. Peer-reviewed scientific literature establishes a link between highly urbanized landscapes and degradation in the aquatic health of non-tidal stream ecosystems.

The results of the BSID analysis, and the probable causes and sources of the biological impairments in Bynum Run watershed can be summarized as follows:

- The BSID analysis has determined that biological communities in the Bynum Run watershed are likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased urban runoff have resulted in streambed scouring and subsequent elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus support the 1996 Category 5 listing for total suspended solids as an impairing substance in the Bynum Run watershed, and links this pollutant to biological conditions in these waters.

- The BSID analysis has determined that biological communities in the Bynum Run watershed are also likely degraded due to water chemistry related stressors. Specifically, acute and chronic ammonia toxicity is a probable cause of impacts to biological communities. Impacts on water quality due to elevated ammonia concentrations is dependent on prolonged exposure; future monitoring of ammonia will help in determining the spatial and temporal extent of this impairment in the watershed.

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2007 WQA for nitrogen and phosphorus was an appropriate management action.

## 1.0 Introduction

Section 303(d) of the federal Clean Water Act (CWA) and the U.S. Environmental Protection Agency's (USEPA) implementing regulations direct each state to identify and list waters, known as water quality limited segments (WQLSs), in which current required controls of a specified substance are inadequate to achieve water quality standards. For each WQLS listed on the *Integrated Report of Surface Water Quality in Maryland* (Integrated Report), the State is to either establish a Total Maximum Daily Load (TMDL) of the specified substance that the waterbody can receive without violating water quality standards, or demonstrate via a Water Quality Analysis (WQA) that water quality standards are being met. In 2002, the State began listing biological impairments on the Integrated Report. Maryland Department of the Environment (MDE) has developed a biological assessment methodology to support the determination of proper category placement for 8-digit watershed listings.

The current MDE biological assessment methodology is a three-step process: (1) a data quality review, (2) a systematic vetting of the dataset, and (3) a watershed assessment that guides the assignment of biological condition to Integrated Report categories. In the data quality review step, available relevant data are reviewed to ensure they meet the biological listing methodology criteria of the Integrated Report (MDE 2008). In the vetting process, an established set of rules is used to guide the removal of sites that are not applicable for listing decisions (e.g., tidal or black water streams). The final principal database contains all biological sites considered valid for use in the listing process. In the watershed assessment step, a watershed is evaluated based on a comparison to a reference condition (i.e., healthy stream, <10% degraded) that accounts for spatial and temporal variability, and establishes a target value for "aquatic life support." During this step of the assessment, a watershed that differs significantly from the reference condition is listed as impaired (Category 5) on the Integrated Report. If a watershed is not determined to differ significantly from the reference condition, the assessment must have an acceptable precision (i.e., margin of error) before the watershed is listed as meeting water quality standards (Category 1 or 2). If the level of precision is not acceptable, the status of the watershed is listed as inconclusive and subsequent monitoring options are considered (Category 3). If a watershed is classified as impaired (Category 5), then a stressor identification analysis is completed to determine if a TMDL is necessary.

The MDE biological stressor identification (BSID) analysis applies a case-control, risk-based approach that uses the principal dataset, with considerations for ancillary data, to identify potential causes of the biological impairment. Identification of stressors responsible for biological impairments was limited to the round two Maryland Department of Natural Resources Maryland Biological Stream Survey (MDDNR MBSS) dataset (2000–2004) because it provides a broad spectrum of paired data variables (i.e., biological monitoring and stressor information) to best enable a complete stressor analysis. The BSID analysis then links potential causes/stressors with general causal scenarios and concludes with a review for ecological plausibility by State scientists.

Once the BSID analysis is completed, one or several stressors (pollutants) may be identified as probable or unlikely causes of the poor biological conditions within the Maryland 8-digit watershed. BSID analysis results can be used together with a variety of water quality analyses to update and/or support the probable causes and sources of biological impairment in the Integrated Report.

The remainder of this report provides a characterization of the Bynum Run watershed, and presents the results and conclusions of a BSID analysis of the watershed.

## 2.0 Bynum Run Watershed Characterization

### 2.1 Location

The Bynum Run watershed drains in to the Bush River which ultimately drains into the Chesapeake Bay (see Figure 1). The watershed is entirely located in Harford County, Maryland. The main transportation corridors in the watershed are Maryland-Route 24, which runs the length of the watershed, and Interstate-95 in the southern portion. The drainage area of Bynum Run watershed is 14,358 acres. The watershed area is located in two (Coastal and Eastern Piedmont) of three distinct eco-regions identified in the MDDNR MBSS Index of Biological Integrity (IBI) metrics (Southerland et al. 2005) (see Figure 2).

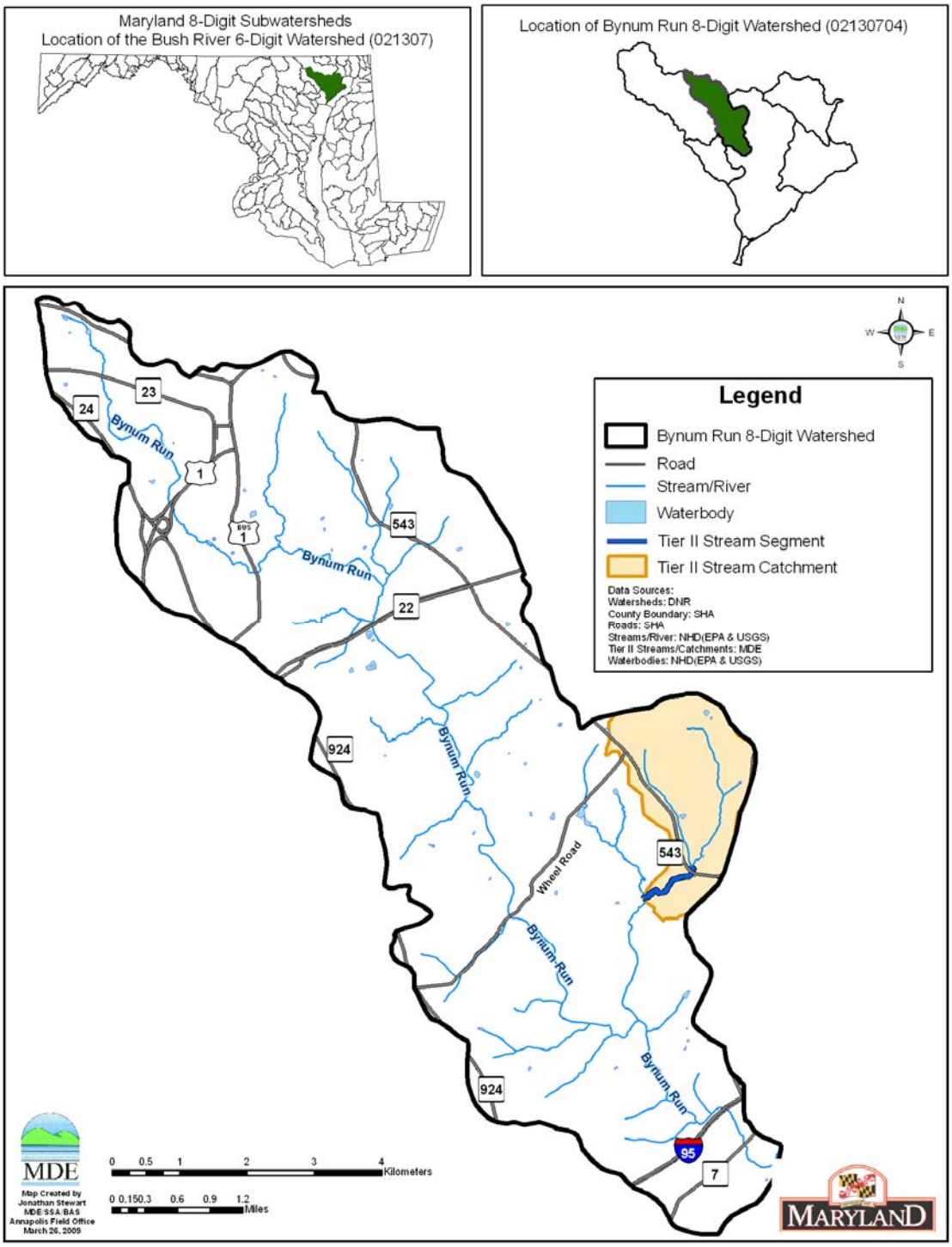


**Figure 1. Location Map of the Bynum Run Watershed**

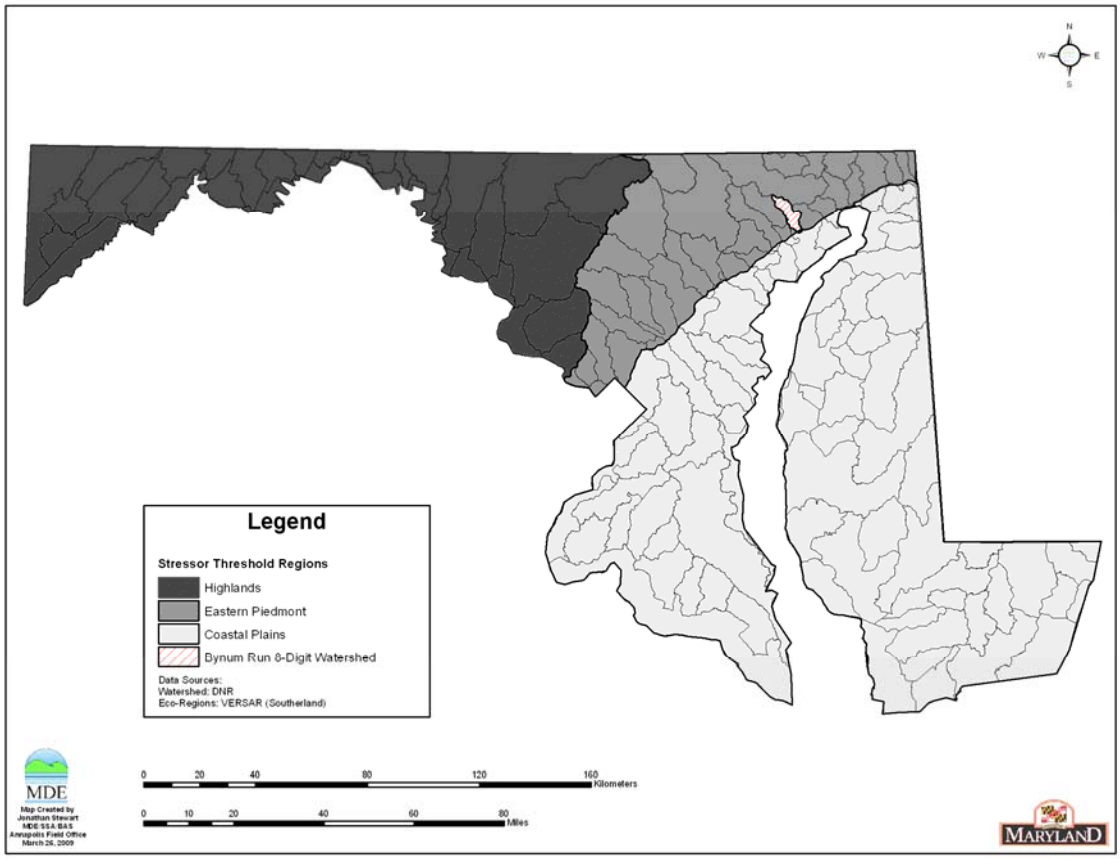


**Figure 2. Eco-Region Location Map of Bynum Run Watershed**

### 2.2 Land Use

The Maryland portion of the Bynum Run watershed comprises 14,358 acres of drainage area in Harford County, Maryland. Most of Bynum Run watershed is a heavily urbanized, densely populated area that was developed many years before there were requirements for managing stormwater runoff quantity and quality changes (see Figure 3). The main transportation corridors in the watershed are Maryland-Route 24, which runs the length of the watershed, and Interstate-95 in the southern portion. The land use distribution in the watershed is approximately 67% urban, 21% forest/herbaceous, and 12% agricultural (see Figure 4) (MDP 2002).

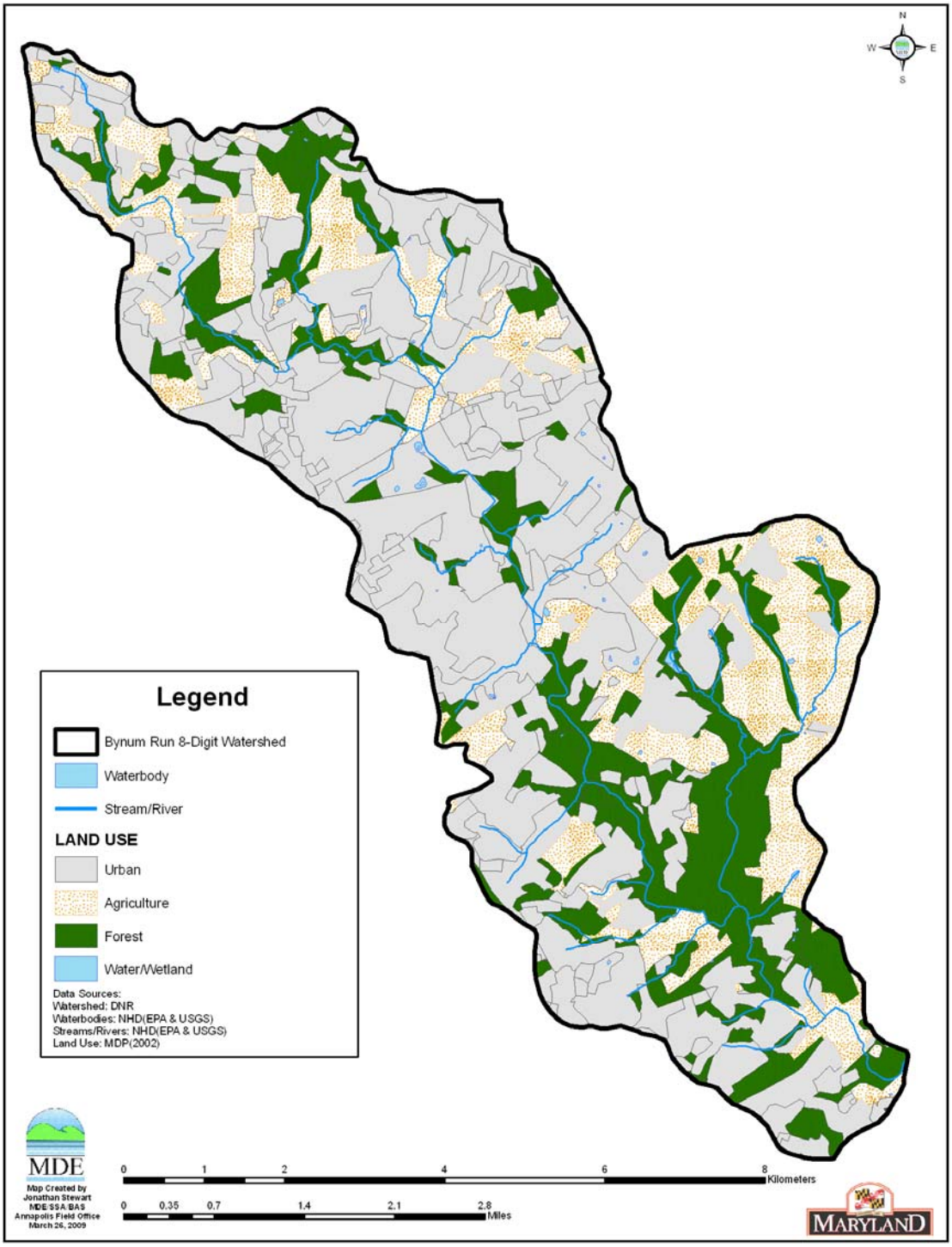


**Figure 3. Land Use Map of the Bynum Run Watershed**

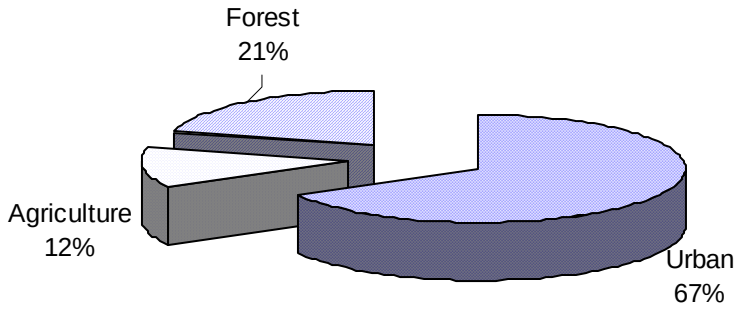


**Figure 4. Proportions of Land Use in the Bynum Run Watershed**

### 2.3 Soils/hydrology

The Bynum Run watershed is predominately within the Piedmont Plateau Physiographic Province of central Maryland with the lower tip extending slightly into the Coastal Plain provinces (Edwards 1981). The Piedmont Plateau Physiographic Province is characterized by gentle to steep rolling topography, low hills and ridges. Broad upland areas with low slopes and gentle drainage characterize the coastal province. The Bynum Run Watershed drains from northwest to southeast, following the dip of the underlying crystalline bedrock in the Piedmont Province. The surface elevations range from approximately 680 feet to sea level at the Chesapeake Bay shorelines. Stream channels of the sub-watersheds are well incised in the Eastern Piedmont, and exhibit relatively straight reaches and sharp bends, reflecting their tendency to following zones of fractured or weathered rock. The stream channels broaden abruptly as they flow down across the fall line into the soft, flat Coastal Plain sediments (CES 1995). Crystalline rocks of volcanic origin consisting primarily of schist and gneiss characterize the surficial geology. These formations are resistant to short-term erosion and often determine the limits of the stream bank and streambed. These crystalline formations decrease in elevation from northwest to southeast and eventually extend beneath the younger sediments of the Coastal Plain. The fall line represents the transition between the Atlantic Coastal Plain and the Piedmont Provinces (CES 1995).

The watershed is comprised primarily of B, C and D type soils with the soil distribution within the watershed being approximately 1% soil group A, 65% soil group B, 15% soil group C and 18% soil group D. Soil data were obtained from Soil Survey Geographic (SSURGO) coverages created by the National Resources Conservation Service. Four

hydrologic soil groups developed by the Soil Conservation Service (SCS) categorize soil type. The definitions of the groups are as follows: Group A: Soils with high infiltration rates, typically deep well drained to excessively drained sands or gravels. Group B: Soils with moderate infiltration rates, generally moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Group C: Soils with slow infiltration rates, mainly soils with a layer that impedes downward water movement or soils with moderately fine-to-fine texture. Group D: Soils with very slow infiltration rates, mainly clay soils, soils with a permanently high water table, and shallow soils over nearly impervious material (SCS 1976).

## 3.0 Bynum Run Watershed Water Quality Characterization

### 3.1 Integrated Report Impairment Listings

The Bynum Run watershed (basin code 02130704), located in Harford County, was identified on the States list of WQLSs and listed in the Integrated Report under Category 5 as impaired by sediments, nutrients (1996 listings), impacts to biological communities (2002 listing) and polychlorinated biphenyls (PCBs)(2006 listing). The Bynum Run watershed was de-listed for nutrients in 2007 following USEPA concurrence with Maryland Department of the Environment's (MDE) analysis of water column data collected during 1998-2004, which showed no nutrients impairment.

### 3.2 Biological Impairment

The Maryland Surface Water Use Designation in the Code of Maryland Regulations (COMAR) for the Bynum Run watershed is Use III – *nontidal cold water* for the mainstem and all tributaries. In addition, COMAR requires these waterbodies to support at a minimum the Use I designation - *water contact recreation, and protection of nontidal warmwater aquatic life* (COMAR a,b). A water quality standard is the combination of a designated use for a particular body of water and the water quality criteria designed to protect that use. Designated uses include support of aquatic life; primary or secondary contact recreation, drinking water supply, and shellfish propagation and harvest. Water quality criteria consist of narrative statements and numeric values designed to protect the designated uses. The criteria developed to protect the designated use may differ and are dependent on the specific designated use(s) of a waterbody.

The Bynum Run watershed is listed under Category 5 of the 2008 Integrated Report as impaired for evidence of biological impacts. Approximately 80% of stream miles in the Bynum Run watershed are estimated as having benthic and/or fish indices of biological impairment in the poor to very poor category. The biological impairment listing is based on the combined results of MDDNR MBSS round one (1995-1997) and round two (2000-2004) data, which include ten stations. Eight of the ten have benthic and/or fish index of

biotic integrity (BIBI, FIBI) scores lower than 3.0 (i.e., poor to very poor). The principal dataset, ie MBSS Round 2 contains five MBSS sites; with four having BIBI and/or FIBI scores lower than 3.0. Figure 5 illustrates principal dataset site locations for the Bynum Run watershed.

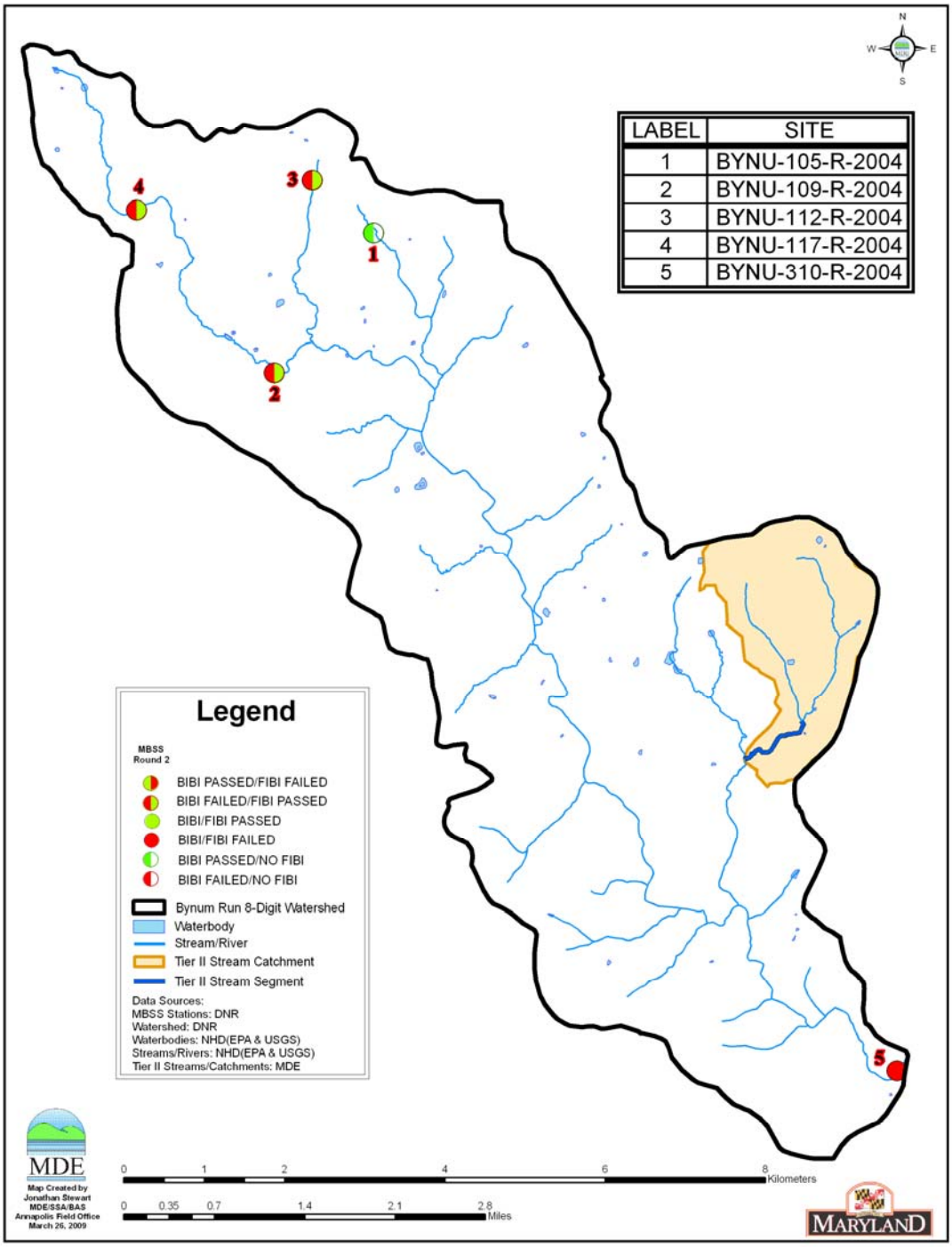


**Figure 5. Principal Dataset Sites for the Bynum Run Watershed**

## 4.0 Stressor Identification Results

The BSID process uses results from the BSID data analysis to evaluate each biologically impaired watershed and determine potential stressors and sources. Interpretation of the BSID data analysis results is based upon components of Hill's Postulates (Hill 1965), which propose a set of standards that could be used to judge when an association might be causal. The components applied are: 1) the strength of association which is assessed using the odds ratio; 2) the specificity of the association for a specific stressor (risk among controls); 3) the presence of a biological gradient; 4) ecological plausibility which is illustrated through final causal models; and 5) experimental evidence gathered through literature reviews to help support the causal linkage.

The BSID data analysis tests for the strength of association between stressors and degraded biological conditions by determining if there is an increased risk associated with the stressor being present. More specifically, the assessment compares the likelihood that a stressor is present, given that there is a degraded biological condition, by using the ratio of the incidence within the case group as compared to the incidence in the control group (odds ratio). The case group is defined as the sites within the assessment unit with BIBI/FIBI scores lower than 3.0 (i.e., poor to very poor).
The controls are sites with similar physiographic characteristics (Highland, Eastern Piedmont, and Coastal region), and stream order for habitat parameters (two groups – 1$^{st}$ and 2$^{nd}$-4th order), that have fair to good biological conditions.

The common odds ratio confidence interval was calculated to determine if the odds ratio was significantly greater than one. The confidence interval was estimated using the Mantel-Haenzel (MH) (1959) approach and is based on the exact method due to the small sample size for cases. A common odds ratio significantly greater than one indicates that there is a statistically significant higher likelihood that the stressor is present when there are very poor to poor biological conditions (cases) than when there are fair to good biological conditions (controls). This result suggests a statistically significant positive association between the stressor and very poor to poor biological conditions and is used to identify potential stressors.

Once potential stressors are identified (i.e., odds ratio significantly greater than one), the risk attributable to each stressor is quantified for all sites with very poor to poor biological conditions within the watershed (i.e., cases). The attributable risk (AR) defined herein is the portion of the cases with very poor to poor biological conditions that are associated with the stressor. The AR is calculated as the difference between the proportion of case sites with the stressor present and the proportion of control sites with the stressor present.

Once the AR is calculated for each possible stressor, the AR for groups of stressors is calculated. Similar to the AR calculation for each stressor, the AR calculation for a group of stressors is also summed over the case sites using the individual site

characteristics (i.e., stressors present at that site). The only difference is that the absolute risk for the controls at each site is estimated based on the stressor present at the site that has the lowest absolute risk among the controls.

After determining the AR for each stressor and the AR for groups of stressors, the AR for all potential stressors is calculated. This value represents the proportion of cases, sites in the watershed with poor to very poor biological conditions, which would be improved if the potential stressors were eliminated (Van Sickle and Paulsen 2008). The purpose of this metric is to determine if stressors have been identified for an acceptable proportion of cases (MDE 2009).

Through the BSID data analysis, MDE identified sediment, in-stream habitat parameters, water chemistry parameters, and potential sources significantly associated with poor to very poor fish and/or benthic biological conditions in the Bynum Run watershed. As shown in Table 1 through Table 3, parameters from the sediment, in-stream habitat, and water chemistry groups are identified as possible biological stressors in the Bynum Run watershed. Parameters identified as representing possible sources are listed in Table 4 and include various urban land use types. Table 5 shows the summary of combined AR values for the stressor groups in the Bynum Run watershed. Table 6 shows the summary of combined AR values for the source groups in the Bynum Run watershed.

## Table 1. Sediment Biological Stressor Identification Analysis Results for the Bynum Run Watershed

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| Sediment | extensive bar formation present | 5 | 4 | 89 | 0% | 13% | No | ---- |
| | moderate bar formation present | 5 | 4 | 89 | 50% | 42% | No | ---- |
| | bar formation present | 5 | 4 | 89 | 100% | 90% | No | ---- |
| | channel alteration marginal to poor | 5 | 4 | 89 | 50% | 41% | No | ---- |
| | channel alteration poor | 5 | 4 | 89 | 0% | 12% | No | ---- |
| | high embeddedness | 5 | 4 | 89 | 25% | 8% | No | ---- |
| | epifaunal substrate marginal to poor | 5 | 4 | 89 | 50% | 13% | Yes | 37% |
| | epifaunal substrate poor | 5 | 4 | 89 | 0% | 3% | No | ---- |
| | moderate to severe erosion present | 5 | 4 | 89 | 50% | 62% | No | ---- |
| | severe erosion present | 5 | 4 | 89 | 0% | 12% | No | ---- |
| | poor bank stability index | 5 | 4 | 89 | 0% | 5% | No | ---- |
| | silt clay present | 5 | 4 | 89 | 100% | 100% | No | ---- |

## Table 2. Habitat Biological Stressor Identification Analysis Results for the Bynum Run Watershed

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| In-Stream Habitat | channelization present | 5 | 4 | 90 | 50% | 9% | Yes | 41% |
| | instream habitat structure marginal to poor | 5 | 4 | 89 | 25% | 13% | No | ---- |
| | instream habitat structure poor | 5 | 4 | 89 | 0% | 1% | No | ---- |
| | pool/glide/eddy quality marginal to poor | 5 | 4 | 89 | 25% | 51% | No | ---- |
| | pool/glide/eddy quality poor | 5 | 4 | 89 | 0% | 1% | No | ---- |
| | riffle/run quality marginal to poor | 5 | 4 | 89 | 75% | 19% | Yes | 57% |
| | riffle/run quality poor | 5 | 4 | 89 | 25% | 1% | Yes | 24% |
| | velocity/depth diversity marginal to poor | 5 | 4 | 89 | 25% | 51% | No | ---- |
| | velocity/depth diversity poor | 5 | 4 | 89 | 0% | 0% | No | ---- |
| | concrete/gabion present | 5 | 4 | 90 | 0% | 1% | No | ---- |
| | beaver pond present | 5 | 4 | 89 | 0% | 4% | No | ---- |
| Riparian Habitat | no riparian buffer | 5 | 4 | 90 | 25% | 24% | No | ---- |
| | low shading | 5 | 4 | 89 | 0% | 8% | No | ---- |

## Table 3. Water Chemistry Biological Stressor Identification Analysis Results for the Bynum Run Watershed

| Parameter Group | Stressor | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with stressor present | % of control sites with stressor present | Possible stressor (Odds of stressor in cases significantly higher than odds of stressor in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Stressor |
|---|---|---|---|---|---|---|---|---|
| Water Chemistry | high total nitrogen | 5 | 4 | 165 | 25% | 47% | No | ---- |
| | high total dissolved nitrogen | 0 | 0 | 0 | 0% | 0% | No | ---- |
| | ammonia acute with salmonid present | 5 | 4 | 165 | 50% | 5% | Yes | 45% |
| | ammonia acute with salmonid absent | 5 | 4 | 165 | 0% | 3% | No | ---- |
| | ammonia chronic with salmonid present | 5 | 4 | 165 | 75% | 15% | Yes | 60% |
| | ammonia chronic with salmonid absent | 5 | 4 | 165 | 50% | 4% | Yes | 46% |
| | low lab pH | 5 | 4 | 165 | 0% | 2% | No | ---- |
| | high lab pH | 5 | 4 | 165 | 0% | 2% | No | ---- |
| | low field pH | 5 | 4 | 164 | 0% | 4% | No | ---- |
| | high field pH | 5 | 4 | 164 | 0% | 2% | No | ---- |
| | high total phosphorus | 5 | 4 | 165 | 0% | 6% | No | ---- |
| | high orthophosphate | 5 | 4 | 165 | 0% | 8% | No | ---- |
| | dissolved oxygen < 5mg/l | 5 | 4 | 164 | 25% | 1% | Yes | 24% |
| | dissolved oxygen < 6mg/l | 5 | 4 | 164 | 25% | 2% | No | ---- |
| | low dissolved oxygen saturation | 5 | 4 | 152 | 25% | 1% | Yes | 24% |
| | high dissolved oxygen saturation | 5 | 4 | 152 | 0% | 0% | No | ---- |
| | acid neutralizing capacity below chronic level | 5 | 4 | 165 | 0% | 1% | No | ---- |
| | acid neutralizing capacity below episodic level | 5 | 4 | 165 | 0% | 7% | No | ---- |
| | high chlorides | 5 | 4 | 165 | 25% | 5% | No | ---- |
| | high conductivity µS/cm | 5 | 4 | 165 | 25% | 6% | No | ---- |
| | high sulfates | 5 | 4 | 165 | 0% | 4% | No | ---- |

## Table 4. Stressor Source Identification Analysis Results for the Bynum Run Watershed

| Parameter Group | Source | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with source present | % of control sites with source present | Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source |
|---|---|---|---|---|---|---|---|---|
| Sources Urban | high impervious surface in watershed | 5 | 4 | 164 | 25% | 3% | No | ---- |
| | high % of high intensity urban in watershed | 5 | 4 | 165 | 100% | 21% | Yes | 79% |
| | high % of low intensity urban in watershed | 5 | 4 | 165 | 0% | 5% | No | ---- |
| | high % of transportation in watershed | 5 | 4 | 165 | 75% | 9% | Yes | 66% |
| | high % of high intensity urban in 60m buffer | 5 | 4 | 164 | 50% | 4% | Yes | 46% |
| | high % of low intensity urban in 60m buffer | 5 | 4 | 164 | 0% | 6% | No | ---- |
| | high % of transportation in 60m buffer | 5 | 4 | 164 | 0% | 6% | No | ---- |

## Table 4. Stressor Source Identification Analysis Results for the Bynum Run Watershed (Cont.)

| Parameter Group | Source | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with source present | % of control sites with source present | Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source |
|---|---|---|---|---|---|---|---|---|
| Sources Agriculture | high % of agriculture in watershed | 5 | 4 | 165 | 0% | 22% | No | ---- |
| | high % of cropland in watershed | 5 | 4 | 165 | 0% | 3% | No | ---- |
| | high % of pasture/hay in watershed | 5 | 4 | 165 | 0% | 29% | No | ---- |
| | high % of agriculture in 60m buffer | 5 | 4 | 164 | 0% | 13% | No | ---- |
| | high % of cropland in 60m buffer | 5 | 4 | 164 | 0% | 3% | No | ---- |
| | high % of pasture/hay in 60m buffer | 5 | 4 | 164 | 0% | 23% | No | ---- |
| Sources Barren | high % of barren land in watershed | 5 | 4 | 165 | 50% | 10% | Yes | ---- |
| | high % of barren land in 60m buffer | 5 | 4 | 164 | 0% | 10% | No | ---- |
| Sources Anthropogenic | low % forest in watershed | 5 | 4 | 165 | 0% | 8% | No | ---- |
| | low % of forest in 60m buffer | 5 | 4 | 164 | 0% | 9% | No | ---- |

## Table 4. Stressor Source Identification Analysis Results for the Bynum Run Watershed (Cont.)

| Parameter Group | Source | Total number of sampling sites in watershed with stressor and biological data | Cases (number of sites in watershed with poor to very poor Fish or Benthic IBI) | Controls (Average number of reference sites with fair to good Fish and Benthic IBI) | % of case sites with source present | % of control with source present | Possible stressor (Odds of stressor in cases significantly higher than odds of sources in controls using p<0.1) | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Source |
|---|---|---|---|---|---|---|---|---|
| Sources Acidity | atmospheric deposition present | 5 | 4 | 165 | 0% | 5% | No | ---- |
| | AMD acid source present | 5 | 4 | 165 | 0% | 0% | No | ---- |
| | organic acid source present | 5 | 4 | 165 | 0% | 0% | No | ---- |
| | agricultural acid source present | 5 | 4 | 165 | 0% | 2% | No | ---- |

## Table 5. Summary of Combined Attributable Risk Values of the Stressor Group in the Bynum Run Watershed

| Stressor Group | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk) | |
|---|---|---|
| Sediment | 37% | 97% |
| In-Stream Habitat | 91% | |
| Riparian Habitat | ---- | |
| Water Chemistry | 94% | |

## Table 6. Summary of Combined Attributable Risk Values of the Source Group in the Bynum Run Watershed

| Source Group | Percent of stream miles in watershed with poor to very poor Fish or Benthic IBI impacted by Parameter Group(s) (Attributable Risk) | |
|---|---|---|
| Urban | 90% | 90% |
| Agriculture | ---- | |
| Barren Land | ---- | |
| Anthropogenic | ---- | |
| Acidity | ---- | |

Sediment Conditions

BSID analysis results for the Bynum Run watershed identified one sediment parameter that has a statistically significant association with poor to very poor stream biological condition: *epifaunal substrate (marginal to poor and poor).*

*Epifaunal substrate* was identified as significantly associated with degraded biological conditions and found in 37% *(marginal to poor* rating) of the stream miles with poor to very poor biological conditions in the Bynum Run watershed. This stressor measures the abundance, variety, and stability of substrates that offer the potential for full colonization by benthic macroinvertebrates. Conditions indicating biological degradation are set at two levels: 1) poor, where stable substrate is lacking, or particles are over 75% surrounded by fine sediment and/or flocculent material; and 2) marginal to poor, where large boulders and/or bedrock are prevalent and cobble, woody debris, or other preferred surfaces are uncommon. Greater availability of productive substrate increases the potential for full colonization; conversely, less availability of productive substrate decreases or inhibits colonization by benthic macroinvertebrates. The Bynum Run watershed is classified as a high gradient stream; the detrimental effects of flashy flows and streambed scouring are exacerbated by this geomorphologic characteristic, thereby reducing the availability of productive substrates.

The majority of the Bynum Run watershed is comprised of urban land uses. As development and urbanization increase in a watershed, so do the morphological changes that affect a stream's habitat. The most critical of these environmental changes are those that alter the watershed's hydrologic regime. Changes to hydrographs are perhaps the most obvious and consistent changes to stream ecosystems influenced by urban land use, with urban streams tending to be more "flashy", i.e., they have more frequent, larger flow events (Walsh et al. 2005). The scouring associated with these increased flows can lead to accelerated channel erosion, thereby increasing sediment deposition throughout the streambed and the settling of sediment in the stream substrate. These processes create an unstable stream ecosystem that can result in a loss of available habitat, continuous displacement of biological communities, frequent re-colonization of biological communities, and a shift in biological communities (i.e, sensitive taxa replaced by more tolerant species).

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the sediment stressor group is approximately 37 % suggesting this stressor impact a moderate proportion of the degraded stream miles in Bynum Run (See Table 5).

In-stream Habitat Conditions

BSID analysis results for the Bynum Run watershed identified three habitat parameters that have a statistically significant association with poor to very poor stream biological condition: *channelization present, riffle/run quality (marginal to poor and poor).*

*Channelization present* was identified as significantly associated with degraded biological conditions and found in 41% of the stream miles with poor to very poor biological conditions in the Bynum Run watershed. This stressor measures the presence/absence of channelization in stream banks. It describes both the straightening of channels and their fortification with concrete or other hard materials. Channelization inhibits the natural flow regime of a stream resulting in increased flows during storm events that can lead to scouring and, consequently, displacement of biological communities. The resulting bank/channel erosion creates unstable channels and excess sediment deposits downstream.

*Riffle/run quality* was identified as significantly associated with degraded biological conditions in the Bynum Run watershed, and found to impact approximately 57% (*marginal to poor* rating) and 24% (*poor* rating) of the stream miles with poor to very poor biological conditions. Riffle/run quality is a visual observation including quantitative measurements based on the depth, complexity, and functional importance of riffle/run habitat within the stream segment. An increase of heterogeneity of riffle/run habitat within the stream segment likely increases the abundance and diversity of fish species, while a decrease in heterogeneity likely decreases abundance and diversity. Riffle/run quality conditions indicating biological degradation are set at two levels: 1) poor, defined as riffle/run depths < 1 cm or riffle/run substrates concreted; and 2) marginal to poor, defined as riffle/run depths generally 1 – 5 cm with a primarily single current velocity. Marginal to poor and poor ratings are expected in unstable stream channels that experience frequent high flows.

All the stressors identified for the in-stream habitat parameter group are intricately linked with habitat heterogeneity. The lower ratings for these habitat parameters indicate lower diversity of a stream's microhabitats and substrates, subsequently causing a reduction in the diversity of biological communities. The flashiness and channelization of the Bynum Run watershed have resulted in channel and streambed alteration within the watershed. The scouring associated with these increased flows leads to accelerated channel erosion, thereby increasing sediment deposition throughout the streambed and decreasing habitat heterogeneity. Channelization has been used extensively in urban landscapes for flood control. However, channelization is detrimental for the "well being" of streams and rivers through the elimination of suitable habitat and the creation of excessive flows. Stream bottoms are made more uniform. Habitats of natural streams contain numerous bends, riffles, runs, pools and varied flows, and tend to support healthier and more diversified plant and animal communities than those in channelized streams. The natural structures impacting stream hydrology, which were removed for channelization, also

provide critical habitat for stream species and impact nutrient availability in stream microhabitats (Bolton and Shellberg 2001). The refuge cavities removed by channelization not only provide concealment for fish, but also serve as traps for detritus, and are areas colonized by benthic macroinvertebrates.

The combination of the altered flow regime, increased sediment, and artificial channelization in Bynum Run has resulted in loss of available habitat and an unstable stream ecosystem. Consequently, an impaired biological community with poor IBI scores is observed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the in-stream habitat stressor group is approximately 91% suggesting these stressors impact almost all of the degraded stream miles in Bynum Run (Table 5).

Riparian Habitat Conditions

BSID analysis results for Bynum Run did not identify any riparian habitat parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in improved biological community).

Water Chemistry Conditions

BSID analysis results for the Bynum Run watershed identified five water chemistry parameters that have statistically significant association with a poor to very poor stream biological condition (i.e., removal of stressors would result in an improved biological community). These parameters are*, acute and chronic ammonia, and dissolved oxygen parameters (low dissolved oxygen < 5mg/L, and low dissolved oxygen saturation).*

*Ammonia acute with salmonid present* is significantly associated with degraded biological conditions in Bynum Run, and found in 45% of the stream miles with poor to very poor biological conditions. Acute ammonia toxicity refers to potential exceedences of species tolerance caused by a one-time, sudden, high exposure of ammonia. Ammonia acute with salmonid present or absent is a USEPA water quality criteria for ammonia concentrations causing acute toxicity in surface waters where salmonid species of fish are present or absent (USEPA 2006). Ammonia ($NH_3$) is a measure of the amount of $NH_3$ in the water column. Ammonia is a nitrogen nutrient species; in excessive amounts it has potential toxic effects on aquatic life. National Pollutant Discharge Elimination System (NPDES) permitted discharges, urban runoff, atmospheric deposition, fertilizers, animal waste, failing septic systems, and leaking wastewater infrastructure are potential sources of ammonia to surface waters. There are six minor municipal, two minor industrial

discharges, and one Municipal Separate Storm Sewer System (MS4) NPDES permitted dischargers in the Bynum Run watershed. Ammonia loads from any wastewater treatment facility is dependent on discharge volume, level of treatment process, and sophistication of the processes and equipment.

*Ammonia chronic* concentrations were identified as significantly associated with degraded biological conditions in Bynum Run, and found to impact approximately 60% (*with salmonid present*) and 46% (*with salmonid absent*) of the stream miles with poor to very poor biological conditions. Chronic ammonia toxicity refers to potential exceedences of species tolerance caused by repeated exposure over a long period of time. Ammonia chronic with salmonid present & absent is a USEPA water quality criteria for $NH_3$ concentrations causing acute toxicity in surface waters where salmonid species of fish are either present or absent (USEPA 2006).

*Low (< 5mg/L) dissolved oxygen* (DO) concentrations are significantly associated with degraded biological conditions and found in 24% of the stream miles with poor to very poor biological conditions in the Bynum Run watershed. Low DO concentrations may indicate organic pollution due to excessive oxygen demand and may stress aquatic organisms. The DO threshold value, at which concentrations below 5.0 mg/L may indicate biological degradation, is established by COMAR 2007.

*Low* (< 60%) *DO saturation* are also significantly associated with degraded biological conditions and found in 24% of the stream miles with poor to very poor biological conditions in the Bynum Run watershed. Natural diurnal fluctuations can become exaggerated in streams with excessive primary production. High and low DO saturation accounts for physical solubility limitations of oxygen in water and provides a more targeted assessment of oxygen dynamics than concentration alone. High DO saturation is considered to demonstrate oxygen production associated with high levels of photosynthesis. Low DO saturation is considered to demonstrate high respiration associated with excessive decomposition of organic material.

The water chemistry stressors (ammonia and low DO) identified by the BSID can be indicative of anthropogenic activities that degrade water quality by causing an increase in contaminant loads from various point and nonpoint sources. These sources can add nutrients and inorganic pollutants to surface waters at levels potentially toxic to aquatic organisms. Most nutrients under natural conditions occur in moderate concentrations and are not generally harmful to aquatic life. Ammonia, on the other hand, is highly toxic to aquatic organisms. Acute ammonia toxicity interferes with physiological processes and leads to cell death in the central nervous system of vertebrates (Randall and Tsui 2002 & Van De Nieuwegiessen 2008).

None of the MBSS stations with elevated ammonia concentrations had low dissolved oxygen, phosphorus, or nitrogen levels. Only one station BYNU-310-R-2004 had low DO (concentration & saturation), which was located near the outlet of the watershed in a highly urbanized area. All other samples taken by MBSS in the watershed were well

above the DO water quality criterion of 5.0 *mg/L.* A water quality station (BYN0007) located with in the watershed monitored by MDE in 1998 thru 1999 totaling eighteen samples, all having DO values above 5.0 *mg/L*. Therefore, this individual sample is not considered indicative of a pattern of failure in the watershed to meet its designated uses.

The MBSS station BYNU-310-R-2004 also did not have elevated phosphorus, nitrogen, or ammonia concentrations. There is no supporting evidence that the ammonia toxicity is related to elevated nutrient concentrations or that excessive eutrophication is occurring in the watershed. The Bynum Run watershed was de-listed for nutrients in 2007 following USEPA concurrence with Maryland Department of the Environment's (MDE) analysis of water column data collected during 1998-2004, which showed no nutrients impairment. Additional analysis of historical, as well as future monitoring data for ammonia will help determine the spatial and temporal extent of this impairment in the watershed.

The combined AR is used to measure the extent of stressor impact of degraded stream miles with poor to very poor biological conditions. The combined AR for the water chemistry stressor group is approximately 94% suggesting that these stressors impact almost all of the degraded stream miles in Bynum Run (Table 5).

Sources

All nine stressor parameters, identified in Tables 1-3, that are significantly associated with biological degradation in the Bynum Run watershed BSID analysis are representative of impacts from urban developed landscapes. High intensity urban land-use in the watershed as well as the sixty meter riparian buffer was significantly associated with degraded biological conditions and found in 79% and 46% of the stream miles with poor to very poor biological conditions. The scientific community (Booth 1991, Konrad and Booth 2002, and Meyer et al. 2005) has consistently identified negative impacts to biological conditions as a result of increased urbanization. A number of systematic and predictable environmental responses have been noted in streams affected by urbanization, and this consistent sequence of effects has been termed "urban stream syndrome" (Meyer et al. 2005). Symptoms of urban stream syndrome include flashier hydrographs, altered habitat conditions, degradation of water quality, and reduced biotic richness, with increased dominance of species tolerant to anthropogenic (and natural) stressors.

Transportation land use in the watershed was significantly associated with degraded biological conditions and found in 66% of the stream miles with poor to very poor biological conditions. There are three main transportation corridors in the watershed are Maryland-Route 24, which borders the western edge and runs the length of the watershed, Route 1, and Interstate-95 in the southern portion. According to Forman and Deblinger (2000), there is a "road-effect zone" over which significant ecological effects extend outward from a road; these effects extend 100 to 1,000 m (average of 300 m) on each side of four-lane roads. Roads tend to capture and export more stormwater pollutants than other land covers.

The BSID source analysis (Table 4) identifies various types of urban land uses as potential sources of stressors that may cause negative biological impacts. The combined AR for the source group is approximately 90% suggesting that urban development potentially impact almost all the degraded stream miles in Bynum Run (Table 6).

Summary

The BSID stressor analysis indicates that the Bynum Run watershed has been significantly impacted by urban development (67% urban land use). The BSID analysis results suggest that degraded biological communities in the Bynum Run watershed are a result of increased urban land use causing alterations to hydrologic regime and stream morphology. The channelization and altered hydrology has caused frequent high flow events, degradation to in-stream habitat quality, and increased sediment loads, resulting in an unstable stream ecosystem that eliminates optimal habitat. In addition, due to the increased proportions of urban land use in the Bynum Run watershed, the stream has experienced an increase in contaminant loads from point and nonpoint sources, resulting in levels of ammonia that can potentially be extremely toxic to aquatic organisms.

Alterations to the hydrologic regime, sedimentation, physical habitat, and water chemistry, have all combined to degrade the Bynum Run watershed, leading to a loss of diversity in the biological community. The combined AR for all the stressors is approximately 97%, suggesting that sediment, in-stream habitat and water chemistry stressors identified in the BSID analysis would adequately account for the biological impairment in the Bynum Run watershed (Table 5).

The BSID analysis evaluates numerous key stressors using the most comprehensive data sets available that meet the requirements outlined in the methodology report. It is important to recognize that stressors could act independently or act as part of a complex causal scenario (e.g., eutrophication, urbanization, habitat modification). Also, uncertainties in the analysis could arise from the absence of unknown key stressors and other limitations of the principal data set. The results are based on the best available data at the time of evaluation.

Final Causal Model for the Bynum Run Watershed

Causal model development provides a visual linkage between biological condition, habitat, chemical, and source parameters available for stressor analysis. Models were developed to represent the ecologically plausible processes when considering the following five factors affecting biological integrity: biological interaction, flow regime, energy source, water chemistry, and physical habitat (Karr, 1991 and USEPA 2007). The five factors guide the selections of available parameters applied in the BSID analyses and are used to reveal patterns of complex causal scenarios. Figure 6 illustrates the final conceptual model for the Bynum Run watershed, with pathways bolded or highlighted to show the watershed's probable stressors as indicated by the BSID analysis.

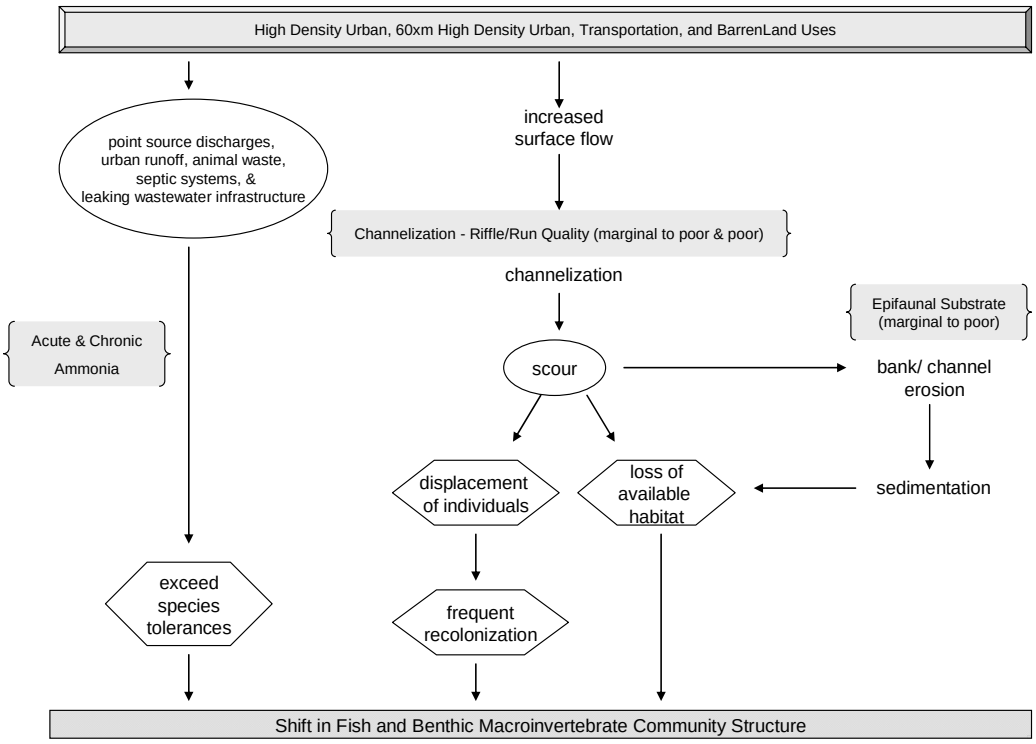


**Figure 6. Final Causal Model for the Bynum Run Watershed**

## 5.0 Conclusions

Data suggest that the Bynum Run watershed's biological communities are strongly influenced by urban land use, which has altered the hydrologic regime resulting in increased sedimentation and increased ammonia toxicity. There is an abundance of scientific research that directly and indirectly links degradation of the aquatic health of streams to urban landscapes, which often cause flashy hydrology in streams and increased contaminant loads from runoff. Based upon the results of the BSID analysis, the probable causes and sources of the biological impairments of the Bynum Run watershed are summarized as follows:

- The BSID analysis has determined that biological communities in the Bynum Run watershed are likely degraded due to flow/sediment related stressors. Specifically, altered hydrology and increased urban runoff have resulted in streambed scouring and subsequent elevated suspended sediment transport through the watershed, which are in turn the probable causes of impacts to biological communities. The BSID results thus support the 1996 Category 5 listing for total suspended solids as an impairing substance in the Bynum Run watershed, and links this pollutant to biological conditions in these waters.

- The BSID analysis has determined that biological communities in the Bynum Run watershed are also likely degraded due to water chemistry related stressors. Specifically, acute and chronic ammonia toxicity is a probable cause of impacts to biological communities. Impacts on water quality due to elevated ammonia concentrations is dependent on prolonged exposure; future monitoring of ammonia will help in determining the spatial and temporal extent of this impairment in the watershed.

- The BSID analysis did not identify any nutrient stressors present and/or nutrient stressors showing a significant association with degraded biological conditions; therefore, the 2007 WQA for nitrogen and phosphorus was an appropriate management action.

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